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5G : A NEW GENERATION OF TECHNOLOGY, BUT WHERE WILL THE INNOVATION COME FROM?

IMT-2020, 3GPP Release 15, or what we now call 5G. Regardless of the name, its rollout comes with a warning: this fifth iteration is more ambitious than its predecessors.

Besides offering speeds ten times faster than its predecessor, 5G promises to address more specific use cases including the Internet of Things (thanks to its greater connection density and tenfold improvement in energy efficiency) and connected vehicles (as a result of its tenfold reduction in latency).

Beyond improvements in radio technology, the core network has been redesigned to improve agility and integrate virtualisation, enabling the creation of sector-specific "virtual networks". This is currently being explored by industries including manufacturing, defense, transport, energy, real estate and healthcare.

As 5G is rolled out across the UK, its new and exciting features are now in the spotlight. But will it deliver on its promises? And where will its success stories emerge?

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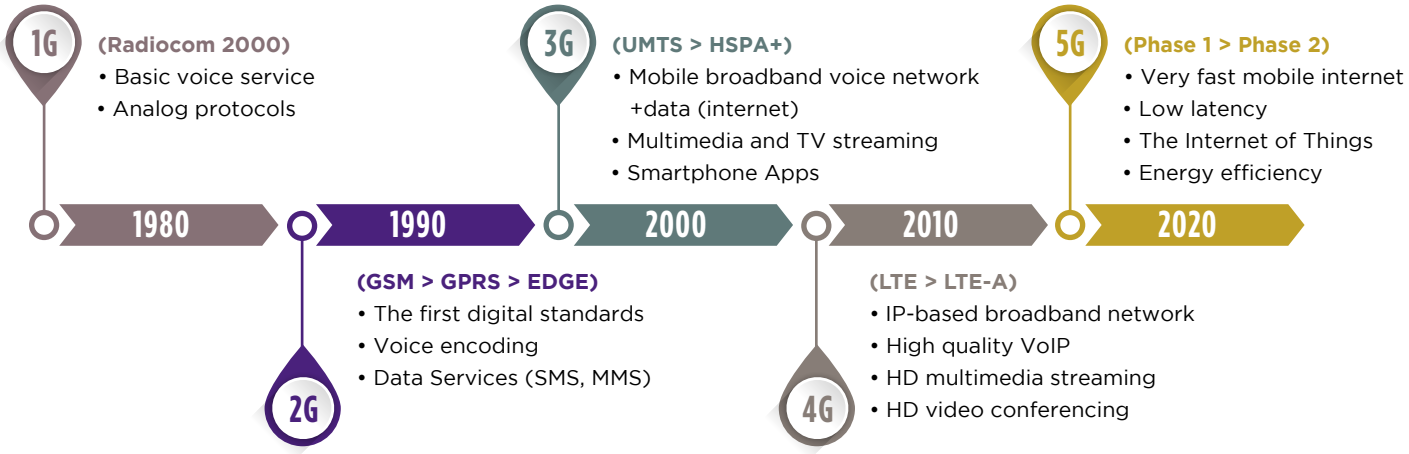
A ROLL OUT UNDER THE GLARE OF THE SPOTLIGHT

The news surrounding the roll out of 5G—a case of déjà vu?
After four generations of mobile networks, we are familiar with the lengthy process of delivering new standards, the debates surrounding frequency auctions, and the corporate launch campaign hype, but this new generation seems to be stirring up exceptionally strong views and debates. 5G is at the centre of a contest that is not only economic, but also political and societal, as shown by the news generated over the last few months.

The five generations of mobile telephony:



Theoretical speed	**10 to 300 kb/s.**	**2 to 20 Mb/s.**	**0.4 to 1 Gb/s.**	**20 Gb/s.**
Loading time for a one-hour, 4k, video at theoretical speeds	**240 to 8 days**	**1 day to 3h**	**8 to 3 min.**	**10 s.**

THE LAUNCH OF 5G: A CONTEST THAT IS BOTH POLITICAL AND ECONOMIC

A dash to launch 5G reminiscent of the space race. We saw the US and South Korea vie for pole position to announce 5G's commercial launch.

Strong pressure from the US on its allies to impose an **embargo on Huawei,** the Chinese 5G network infrastructure manufacturer, over espionage concerns.

Numerous questions raised on **health risks**, especially in Brussels and some Swiss regions, where 5G is deeply unpopular.

Debates over the processes for auctioning frequencies; the **risks associated with soaring license prices** (as in Germany), which can reduce operators' ability to invest in roll out and geographic coverage. This also highlights the barriers for **new players to participate in the auctions**, beyond the current mobile network operators.
The tension surrounding the launch of this new generation of mobile networks demonstrates that we are not just seeing the emergence of yet another version of an already-mature technology—we are experiencing the first wave of a phenomenon that will profoundly disrupt all sectors of the economy over the next decade.

THE LATEST IN A LONG LINE OF NEW GENERATIONS

5G is the latest iteration in a long line of mobile networks. Each new generation has resulted in strong growth rates and new services, things that have changed our relationship with mobile telephony. New uses (such as instant messaging, video and social networking) have taken precedence over the original telephony uses. And, once again, this fifth generation may transform habits well beyond our current use of smartphones.

MAJOR TECHNICAL DEVELOPMENTS
In specifying this fifth generation of mobile radio spectrum standards, the ITU (the International Telecommunication Union) has defined the performance objectives around **eight KPIs.**
The results are impressive with performance typically increasing by a factor of ten compared with the previous generation.

MUCH MORE THAN JUST VERY HIGH SPEEDS...

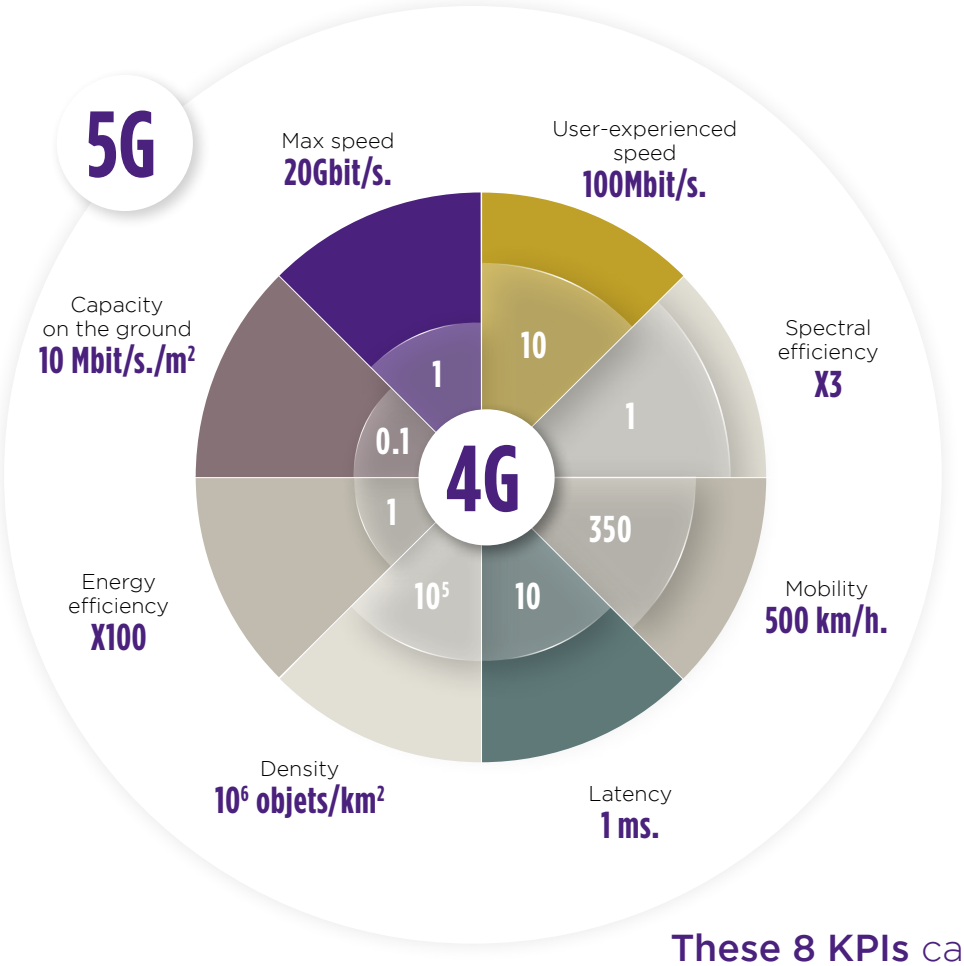
Speeds 10 to 20 times higher: 20Gb/s at peak and 100Mb/s in terms of user experience (that's 60,000 times faster than 2G, the first generation to carry data!).

A **connection density** that can reach a million connected objects per square kilometre.

A **latency** of the order of a millisecond, 10 to 15 times lower than that of 4G.

Power consumption reduced by a factor of 100.

Improvements offered by 5G compared to 4G—according to it's 8 KPI's:



These 8 KPIs cannot all be **achieved simultaneously**

To achieve this level of performance, the specification for the entire communication chain has been redesigned—**radio interfaces and antennas, as well as the core network.** However, it's important to highlight that these performance objectives cannot all be achieved at the same time.

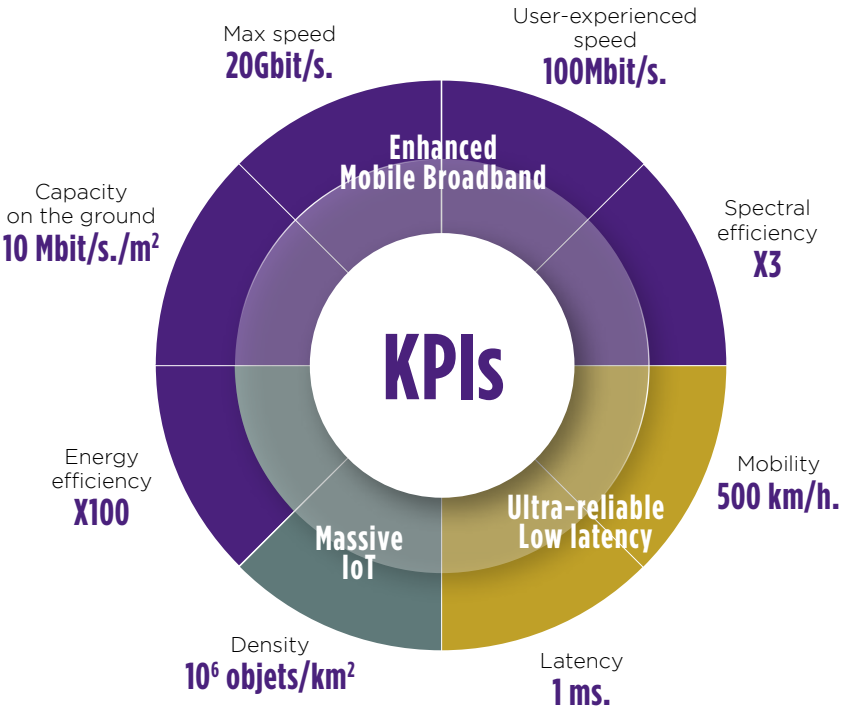
Three variants have been defined to address the main predicted use cases:

Enhanced Mobile Broadband (eMBB), where efficiency of frequency usage focuses on increasing **current mobile internet speeds** (4k video, virtual reality, etc.).

Massive Machine Type Communication (mMTC) **or Massive IoT** which aims at high object-density and low power consumption in order to support the development of the Internet of Things (the IoT).

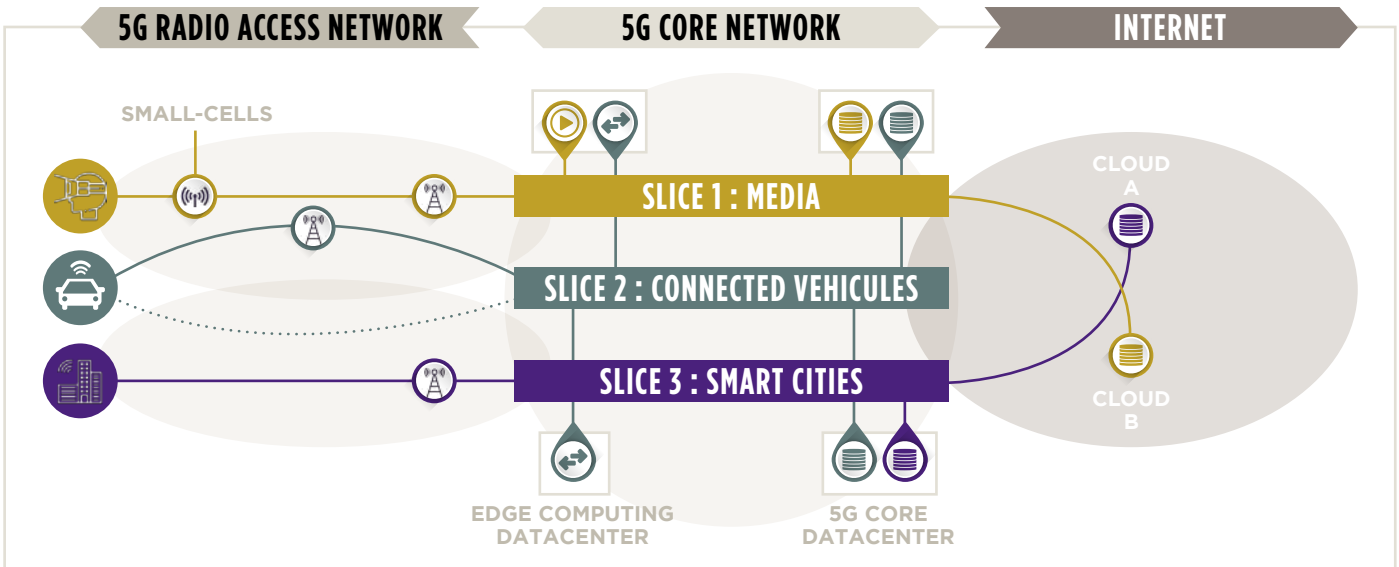
Ultra-Reliable & Low Latency (URLL): Low latency and connection stability for devices traveling at high speeds (up to 500km/h), which can meet the challenges **smart vehicles** have to communicate with each other (V2V) and with road infrastructure (V2I).

Three variants adapted to the key use cases:



Small Cells:
Coverage of zones
with small areas
but requiring very
high speeds

The 5G network: an overview of the architecture



NEW ANTENNA TECHNOLOGIES

Other innovations at the antenna-level can improve performance and frequency usage efficiency. Here, massive MIMO (Multiple Inputs Multiple Outputs) improves the techniques already in use for 4G and WiFi, and consists of transforming a single antenna into a grid of micro antennas.
The transmission and reception at each of these micro antennas make it possible to concentrate the power emitted in a given direction, improving transmission performance. This is known as “beamforcing”.

NETWORK SLICING: SLICES FOR ALL USES

The core network, which connects the radio antennas to the internet, is also undergoing development. It is in the process of adopting virtualisation principles and CPCU (control plane/user plane) decoupling.
Dissociating logical network-control functions from physical infrastructure, such as antennas, allows the network to automatically adapt to user needs.

By combining these technologies, 5G operators can generate on-demand instances of **independent virtual networks** (using the same physical infrastructure), which have their own resources and are **tailored to each use case.**
This essentially cuts the network into slices of varying thickness, which has been termed “Network Slicing“.

THE MILLIMETER FREQUENCIES REVOLUTION

The frequencies planned for 5G can be divided into three broad categories: low frequencies (<1GHz), medium frequencies (between 1 and 6GHz), and high frequencies (above 20GHz).

The first two frequency bands have already been partially exploited by previous mobile network generations (2G/3G/4G), and also by WiFi and other technologies. They provide a good compromise between speeds and coverage capacity.

Conversely, the high frequency band is innovative because it is rarely used. These frequencies are deemed as “millimetric“ because their wavelengths are measured on the order of millimetres.

Using these high frequencies enable very high data transfer rates, however the resulting small wavelengths are more sensitive to interference, thus making it more difficult to penetrate buildings.

They are best used to cover small areas which require very high speeds or have a high density of users. These are referred to as “small cells“.

The expansion of antennas is already in place for some facilities, such as stadiums, stations and airports, and it is likely to become more widespread with the use of millimetre waves.

Network slices can be put in place for specific use cases like smart cities, connected cars, delivery drones and emergency services.

Each slice has its own dedicated resources (frequencies, computing capacity, storage and data dissemination capacities) designed for and adapted to its specific needs. The goal is to guarantee security, availability, and performance for each use, which is essential for the development of services.

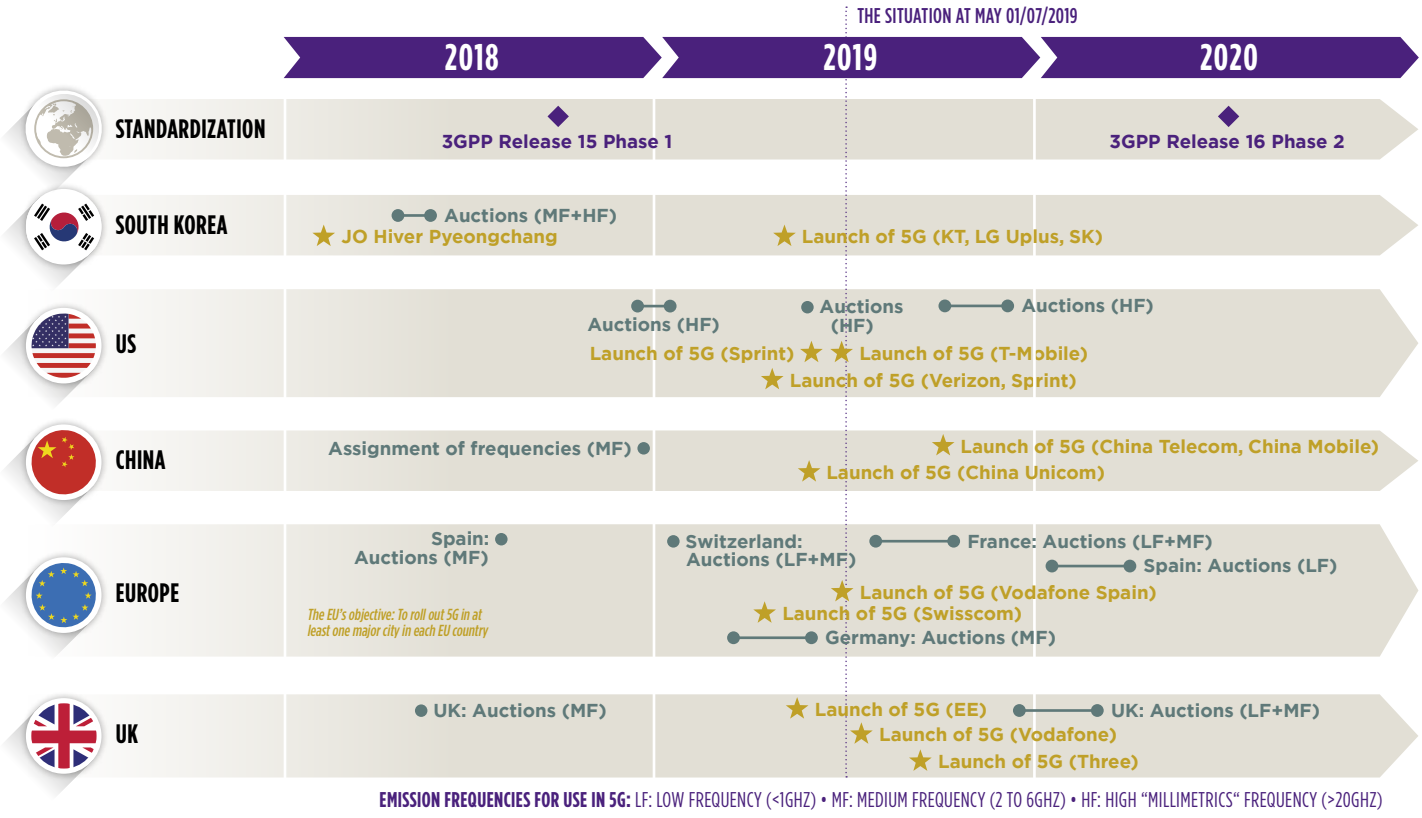
Network Slicing:
Guaranteeing **security, performance, and service quality**
for each use

THE DEVELOPMENT OF 5G

THE FIRST STEPS

A great deal of work has been carried out in parallel by the ITU and 3GPP to test and validate the technologies to achieve the first 5G launch.

With experimental networks launched by operators and manufacturers around the world, the race is on to obtain frequencies and launch services.



EMISSION FREQUENCIES FOR USE IN 5G: LF: LOW FREQUENCY (<1GHZ) • MF: MEDIUM FREQUENCY (2 TO 6GHZ) • HF: HIGH "MILLIMETRICS" FREQUENCY (>20GHZ)

While waiting for the auctions of low and medium frequencies in the UK, operators have announced their 5G launch dates. EE became the first operator to launch its service in 6 cities on 30th May. Vodafone is the second with its 5G network launched on 3rd July. Two other large operators, Three and O2, also confirmed that 5G services will be available later in 2019.

South Korea announced the commercial launch of 5G services in April, a few hours ahead of the US. They were then followed by other countries, notably Switzerland and Spain.

One of the largest Chinese operators launched its 5G services in May across the country and two more operators' 5G services will go live in September.
The EU's roadmap requires each country to have 5G live in at least one major city in 2020, and to have all urban areas and major transport routes covered by 2025.
However, these 5G service launches are based on early versions of 5G (Release 15).

Release 15 partially reuses 4G network infrastructure, which can mask the realities of 5G's launch in terms of geographic coverage (limited cities only), available speeds, and the functionalities provided.

The second version (Release 16) is expected to roll out at the start of 2020, which will lead to the progressive development of infrastructure, solutions, and, above all, mark the true realisation of the new uses that 5G promises.

THE GOVERNMENT LEADS THE WAY IN THE UK

The UK Government has ambitions for the UK to become a global leader in the deployment of 5G and in 2017 launched "The 5G Testbeds and Trials Programme" to take early advantage of the benefits 5G technology offers.
The 5G Innovation Centre at University of Surrey, University of Bristol and King's College London were awarded £16 million to develop the world's first end-to-end 5G test network.

To date the programme has achieved:

- A fully virtualised mobile network for eMBB and URLLC use cases
- Ultra-low latency 5G tactile internet developments with Internet of Skills applications
- Deployment of 5G capabilities in Smart City and Smart Campus testbeds
- Software defined network technologies

A national "5G Innovation Network", currently consisting of 850 organisations, was created to support research and development and collaboration within the industry.

In October 2018, the UK Government launched a competition to provide funding for 6 use case trials with £41 million of investment. Projects were developed and run by a consortium of organisations which includes universities, mobile network operators, and technology companies. The projects covered a range of use cases within agriculture, broadcasting, and utility and connectivity improvements, including:

- AR and VR to enhance the tourist experience
- Connected and autonomous vehicles with network slicing
- Health and social care applications for disadvantaged communities
- Assisted maintenance using robotics, big data analytics and AR over 5G to increase industrial productivity

The UK Government is also seeking to fund additional projects to develop 5G technologies in areas including security, public transportation, rural and urban connectivity, and international collaboration.
The Government is committed to invest £740m to support next generation connectivity (full fibre network deployment) and 5G Testbeds & Trails programmes.

Summary of Participating Stakeholders in UK Use Case Trials (Phase 1 Projects):

5G TRIALS AROUND THE WORLD

UK Focus
In addition to government initiatives, mobile network operators have been conducting R&D activities throughout the UK. Last year, O2 deployed 2 Massive MIMO with Nokia in Kings Cross and Marble Arch, where there is a high density of client devices.
EE has been trialling 5G in Canary Wharf and parts of East London. They also broadcasted the Wembley Cup Final 2018 live over 5G using remote production.
Vodafone set to carry out 5G New Radio field trial collaborations with Nokia and Qualcomm and has completed the UK's first live holographic call over 5G.
Three has demonstrated superfast 5G home broadband in collaboration with Huawei.

Aside from commercial launches, 5G is already a reality in the form of one-off trials.

As early as 2018, spectators at the Winter Olympics in Pyeongchang, South Korea, used 5G to experience bobsleigh runs from the athletes' point of view via live streaming and virtual reality. Audience members could also watch skating events from any angle as they were captured by hundreds of cameras around the rink.

In 2019 the first surgical operations to leverage 5G were conducted; at the MWC (Mobile World Congress) in Barcelona a surgeon assisted a team operating on a tumour at the hospital next door; then, a doctor in China performed remote brain surgery on a patient 3,000km away.

In Finland, Nokia and Telia have implemented 5G in a host of areas: the remote control of automated buses in Helsinki, the remote assistance of an expert in a Factory 4.0 setting, and an online gaming competition (eSports).

NEW SERVICES TO INVENT
NEW BUSINESS MODELS TO DEFINE

B2B-FOCUSED USES WITHIN AN ECOSYSTEM THAT IS EXPERIENCING LITTLE DEVELOPMENT

Looking beyond the most publicised use cases, technology's potential seems almost unlimited in many sectors:

The Enterprise: 5G can have massive benefits to the enterprise. For example, it can provide instant and reliable connectivity for remote working, particularly in rural areas. Within the office environment, it can enhance the corporate network by acting as a backup to provide additional resilience.

Health: Technology can greatly increase the widespread adoption of telemedicine. It can help doctors conduct remote examinations and even remote surgery. This can facilitate access to healthcare in isolated countries or areas where competent medical practitioners are sparse.

Entertainment: 5G's very high speeds offer the option of streaming ever-more enhanced video, allowing 360° immersion and very high definition. Its low latencies will facilitate the development of multiplayer online games, and virtual or augmented reality—including in mobile settings (in cars, on trains, etc.).

Transport and Automotive: The low latency and reliability of mobile connections (for vehicles traveling up to 500km/h) enable critical, real-time communications needed for autonomous cars to be envisaged, and the same goes for rail transport and traffic management in zones where movements are very dense. To illustrate this, a vehicle traveling at 60mph will be able to receive a warning signal in the time it would take for it to travel just a few centimetres—a much shorter interval than the reaction time of a driver.

Emergency Services: The reliability of mobile connections and network slicing could make 5G a credible alternative to replace aging PMR solutions (radio transmission systems used by public authorities such as the police or fire service) by creating **a 5G network slice reserved for emergency services,** and guaranteeing its availability and confidentiality. Broadband and low latency could enable the exchange of tactical information and the transmission of 4k video streams.

Smart Cities and the IoT: Smart cities provides masses of potential uses for managing energy, mobility, water and waste. 5G will have to cope with competing technologies that have already demonstrated effectiveness (such as LoRa and Sigfox), as well as some extensions of 4G, such as the NB-IOT and LTE-M standards.

Agriculture: the potential for very high connection density could facilitate the massive deployment of IoT sensors (up to one per square metre) to improve the targeting of crop treatments (watering, fertilisation, etc.), or even harvesting. On farms, individual animals could be equipped with 5G enabled collars for monitoring.

Industry 4.0: 5G has the potential to be a catalyst for the factory of the future, with the implementation of next generation robots (thanks to low-latency connectivity), the use of sensors to facilitate predictive maintenance, or the deployment of AR/VR (Augmented/Virtual Reality) solutions to assist technicians in repairing increasingly complex machine tools.

The main uses envisaged for 5G's three variants:

1 ENHANCED MOBILE BROADBAND

- Very high-speed mobile (>1Gbit/s)
- Live video in very high definition (UHD)
- 3D and 360° immersive videos
- Mobile access to the cloud
- Massive multiplayer online games

2 ULTRA-RELIABLE AND LOW LATENCY COMMUNICATIONS

- Virtual and augmented reality
- Industrial automation
- Autonomous vehicles
- Critical and real-time applications
- Remote surgery
- Emergency services
- Video for tactical teams and special forces
- Traffic management for drones

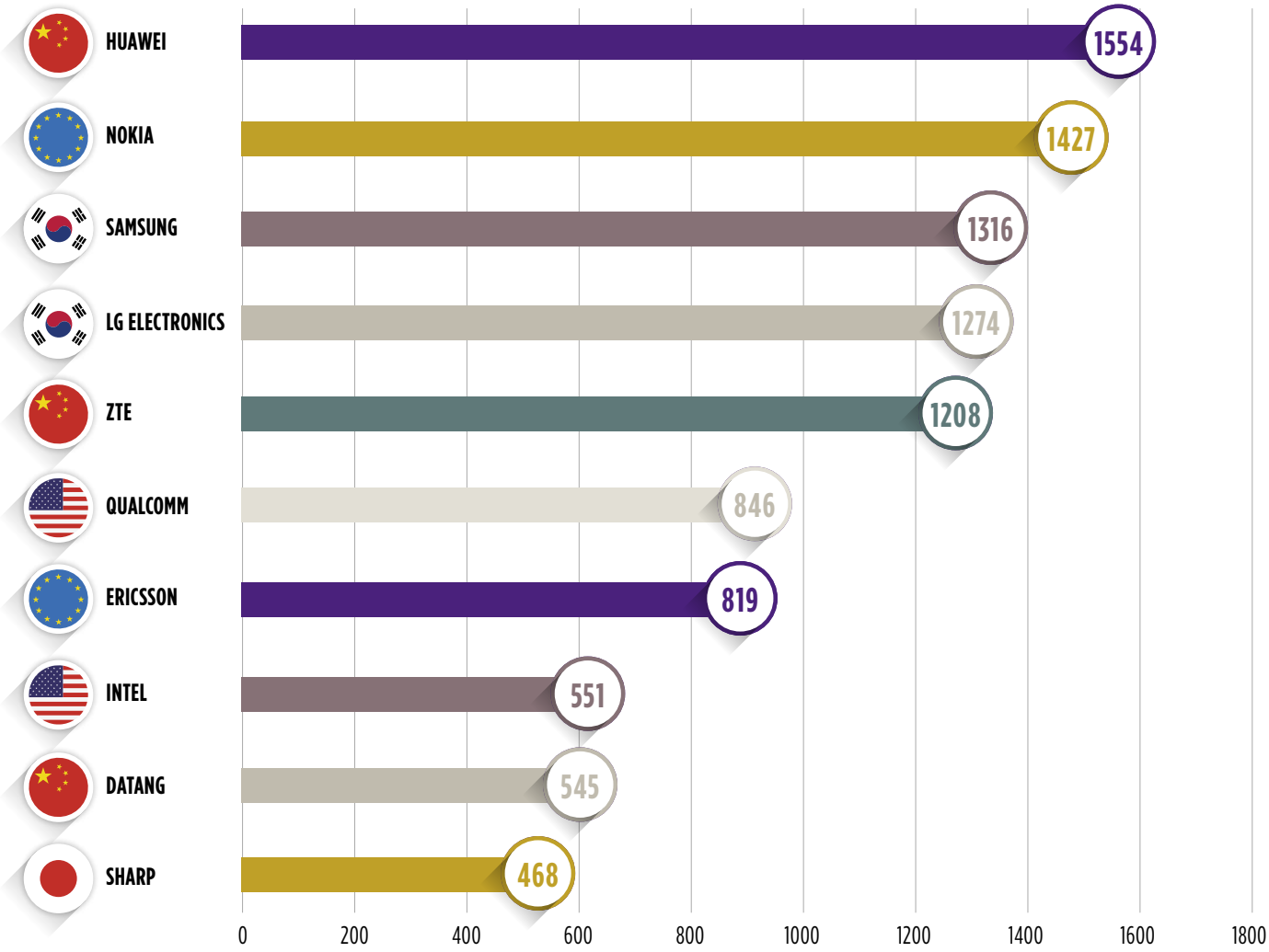
3 MASSIVE MACHINE TYPE COMMUNICATIONS

- Smart Cities
- Smart Homes/Buildings
- Smart Grids
- IoT sensors and remote control
- Farm robots
- Drone swarms

Despite the potential innovative uses, the mobile network ecosystem has yet to be disrupted. The leading players in 5G are the same as for previous mobile network generations.

China is leading with Huawei, ZTE, and Datang, which are among the Top-10 companies in terms of holding the largest number of essential patents for 5G.
They are followed by Korea (Samsung and LG), and then Europe (Nokia and Ericsson), and finally the US (Qualcomm and Intel, which are limiting themselves to 5G chip sets).

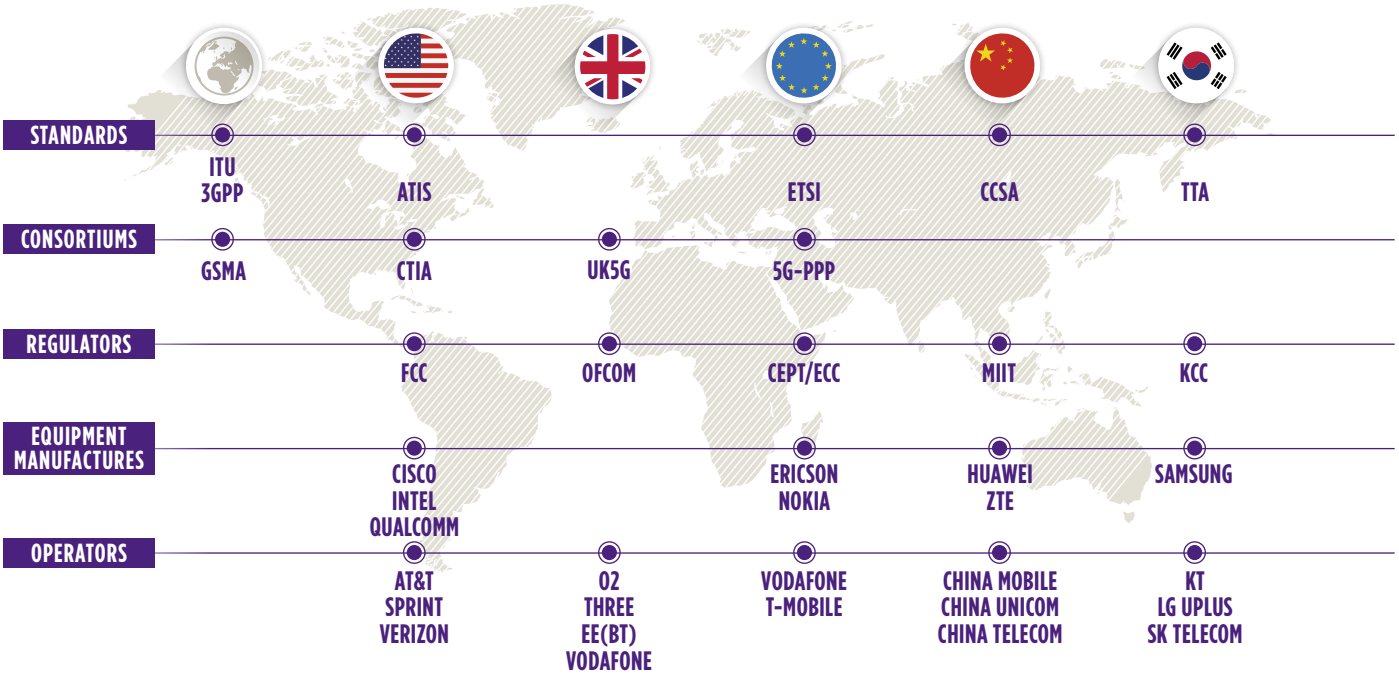
The Top-10 essential patent holders for 5G:



THE INVESTMENT

For this fifth generation of mobile networks, mobile operators will have to invest in purchasing frequencies, in infrastructure (antennas, networks and data centres), and in deployment (cell densification, installing fibre to antennas, etc.).
These investments are essential to stay in the running as 5G appears to be a mobile network generation that will see widespread uptake.
But the profitability of such investments raises questions given that the roll out of 4G is relatively recent and ARPU (average revenue per user) has decreased slightly or, at best, stagnated in the last five years.
If growth seems difficult to find among the general public, operators will have to look to growth drivers among B2B services, an area where use cases are abundant.
This, however, requires additional investments to implement "Network Slicing" and create Massive IoT and/or Ultra-Reliable & Low Latency offerings.
Faced with such a range of possible use cases, it's difficult for operators to segment the network and put in place the associated offerings in advance.
Some uses will probably never see the light of day, and others are likely to offer only low profitability.
Operators are therefore favouring co-construction approaches with specialist players in order to share investments and ensure that the use cases implemented have value.
Finding the right balance in the value chain will nevertheless remain a challenge.

Overview of 5G Key Players:



WHEN THE GAFAM PLAYERS AWAKEN...

Mobile network operators will certainly continue to play a role in the digitalisation of new sectors, but doing this could also attract the attentions of new players.
Yet, to date, the GAFAM companies (Google, Apple, Facebook, Amazon, and Microsoft) have remained relatively restrained in terms of their investments in 5G; these have been limited to a small number of exploratory projects to improve internet coverage in white zones using airships, high altitude drones (in Google's case), and low-orbit satellites for Amazon.
However, 5G presents some key new opportunities in terms of the GAFAM players' strategic interests:

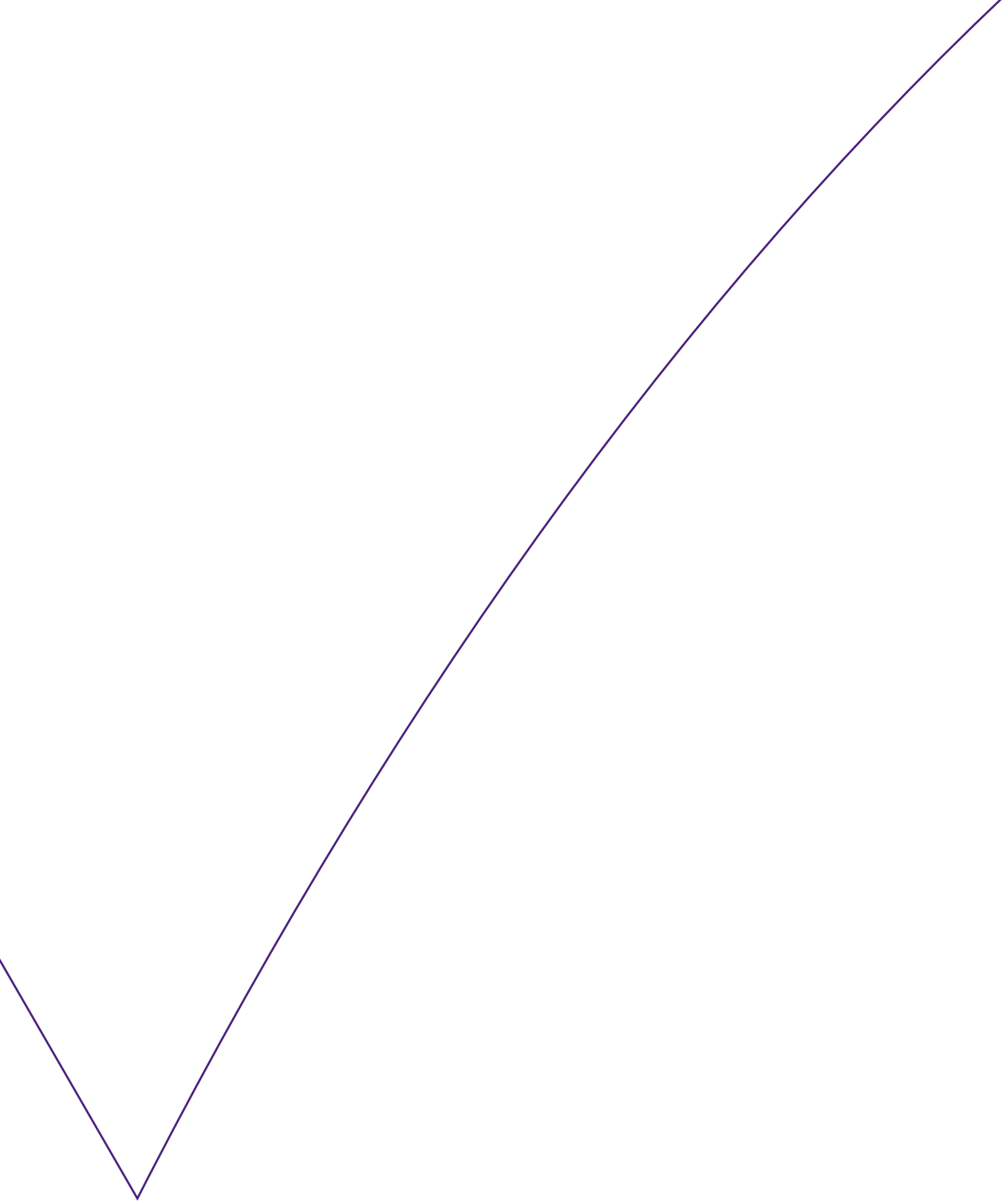
Data collection: Beyond smartphones, 5G will connect a range of objects that will result in a new mass of data with the potential to be exploited.

Logistics: For autonomous cars, 5G can be a traffic-management accelerator for fleets of vehicles and delivery drones.

Cloud and Edge Computing: 5G will not only provide access to the cloud, it will also consume its computing resources to operate. In addition, to benefit from the low latencies that 5G offers, some use cases will need to position their computation and storage resources closer to mobile network users and no longer in the cloud. This is "Edge Computing", something the GAFAM players already have a keen interest in.

The market surrounding IoT is already well structured (because it has already been developed—based on previous technologies) in particular for Industry 4.0, but also for Smart Grids, Smart Cities and Smart Buildings.

On the other hand, **the future expansion of the connected and autonomous vehicles and drones markets have the potential to drive the growth required to support 5G investments in the coming years.**
These value chains have yet to be fully defined and the high number of players involved only adds to the complexity; an area to keep a close eye on for the future.



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